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NETGEN REVISITED: A PROGRAM FOR GENERATING LARGE SCALE (UN)CAPA--ETC(U)
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6 NETGEN REVISITED:
A PROGRAM FOR GENERATING
LARGE SCALE (UN)CAPACITATED
ASSIGNMENT, TRANSPORTATION, AND
MINIMUM COST FLOW NETWORK PROBLEMS

by

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ABSTRACT

The purpose of this note is to describe a modified version of the computer program NETGEN, which can be used to generate network flow problems for testing and validation purposes. The paper also presents solutions for a set of 35 benchmark problems.

1.0 INTRODUCTION

Since its release in 1974, the network flow problem generator NETGEN [1] has gained wide acceptance and has been used in numerous computational studies. As would be expected with any new system, NETGEN users have encountered a few difficulties in its use, and the purpose of this paper is to describe a modification of NETGEN designed to overcome these problems.

Two significant changes, the replacement of the random number generator by a simple congruential generator and conversion to all integer arithmetic, have been made to improve computational speed and enhance portability. All other alterations have been to correct known bugs, e.g., the generation of negative supplies and demands in certain very rectangular transportation problems and the double use of a single random number in generating the cost on uncapacitated non-skeleton arcs. The basic operation of NETGEN, its capabilities, and the structure of the generated problems have not been altered.

2.0 MODIFICATIONS

The two primary difficulties that have arisen in the use of NETGEN have concerned computational speed and reproducibility of results on different computers. Both of these problems have been corrected in the current version.

To improve performance, a simple congruential pseudo random number generator [2, 3] has been installed. This generator, currently used in

the IMSL software, is defined as follows:

$$R_{i+1} = 7^5 * R_i \bmod (2^{31}-1)$$

$$1 \leq R_0 < 2^{31}-1$$

This generator has been demonstrated to possess satisfactory statistical properties [2] and performs an order of magnitude faster than the original generator. Network problems produced using the new generator appear to offer the same degree of solution difficulty, both in terms of total execution time and number of iterations.

Generation of parameters in the original version of NETGEN involved the generation of a uniformly distributed random variable in the interval (0,1). Because of round-off and differing word lengths on various computers, this procedure did not always produce consistent results. To enhance portability, the current version of NETGEN uses only integer arithmetic and its results should be reproducible on any computer having exact integer arithmetic with truncated integer division (e.g., 9/5=1) and at least 31 bits of precision exclusive of sign.

3.0 BENCHMARKS

For purposes of validation, Figure 1 contains the skeleton and Figure 2 contains the completed network generated by NETGEN using the input specifications in Table I. The costs and capacities of each arc are given in Table II in the same format as they appear on the problem file (see Appendix).

Table III gives the problem specifications for the set of 35 test

problems described in [1], and Table IV contains the optimal objective function values for these problems.

Table I

ITEM	NODES	SOURCES	SINKS	ARCS	COST RANGE MIN	COST RANGE MAX	TOTAL SUPPLY	TRANSHIPMENT SOURCES	TRANSHIPMENT SINKS	PERCENT HI COST	PERCENT CAPAC.	UPPER BOUND RANGE MIN	UPPER BOUND RANGE MAX	RANDOM NO. SEED
QUANTITY	14	3	4	32	1	100	750	1	2	35.00	70.00	100	400	12345678

Figure 1

Skeleton Created for the Specifications in Table I

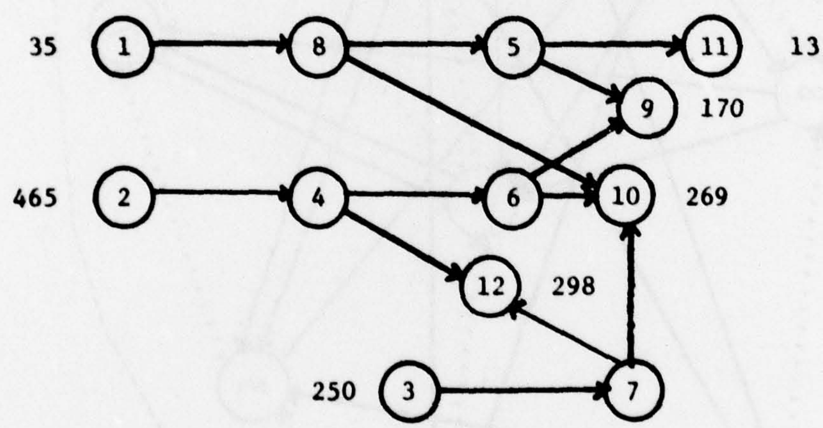

Figure 2
Completed Network

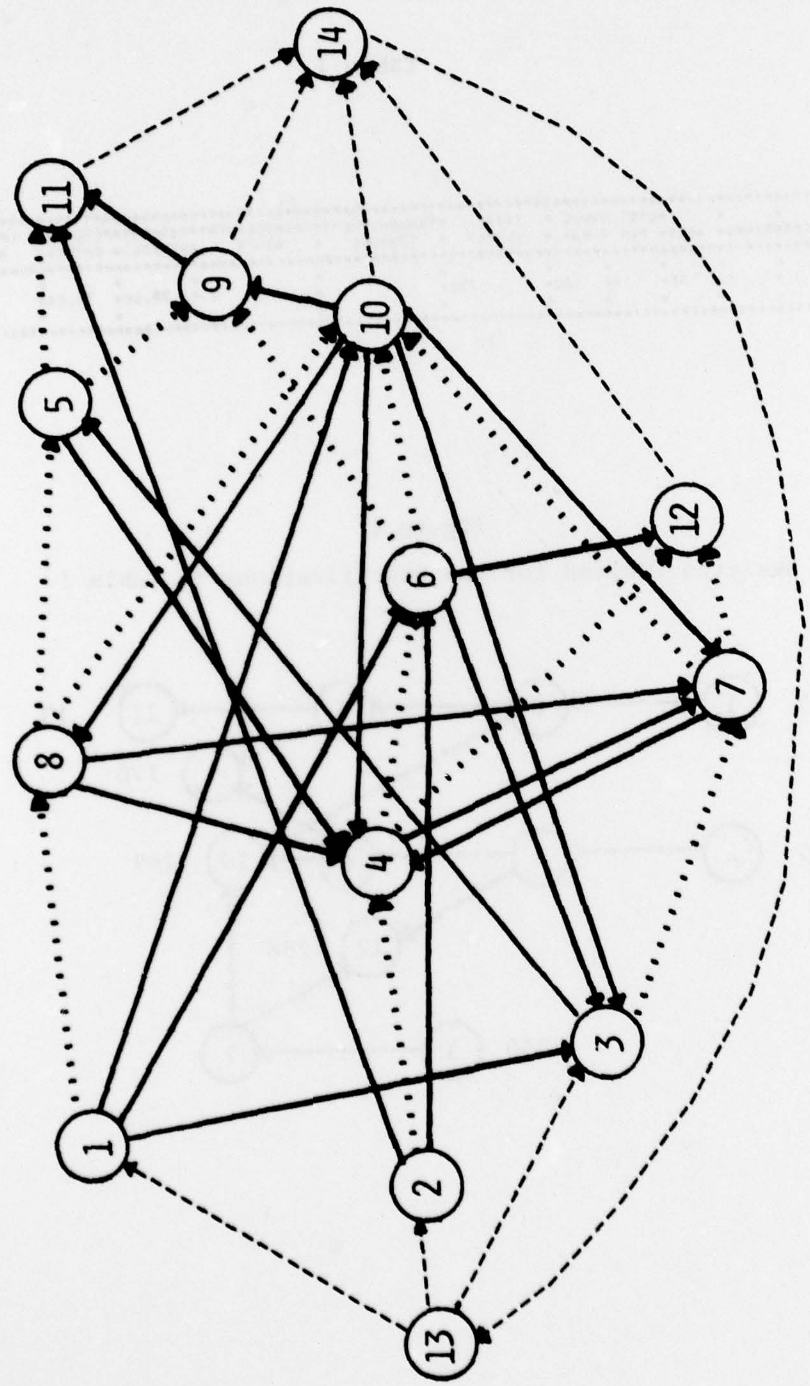

TABLE II

Arc Parameters

FROM NODE	TO NODE	COST	UPPER CAPACITY	LOWER CAPACITY
13	1	0	35	
13	2	0	465	
13	3	0	250	
1	8	100	100	
1	6	13	750	
1	3	60	339	
1	10	94	267	
5	11	100	100	
5	9	38	100	
5	4	51	750	
8	5	100	100	
8	10	23	100	
8	7	82	115	
8	4	92	275	
2	4	38	750	
2	11	57	135	
2	6	53	750	
4	6	100	465	
4	12	100	750	
4	7	82	213	
6	9	93	465	
6	10	100	750	
6	3	66	750	
6	12	87	301	
3	7	68	750	
3	5	81	750	
7	10	100	250	
7	12	26	250	
7	4	50	154	
9	14	0	170	
9	11	95	233	
10	14	0	269	
10	7	76	750	
10	9	93	750	
10	8	11	319	
10	4	38	750	
10	3	41	750	
11	14	0	13	
12	14	0	298	
14	13	0	750	750

Table III
PROBLEM SPECIFICATIONS

	Number of Nodes	Number of Sources	Number of Sinks	Number of Arcs	Cost Range Min	Cost Range Max	Total Supply	Transshipments Sources	Transshipments Sinks	Percent High Cost	Percent of Arcs Capacitated	Upper Bound Range Min	Upper Bound Range Max	Random No. Seed
1.	200	100	100	1300	1	100	100,000	0	0	0	0	0	0	13502460
2.	200	100	100	1500	1	100	100,000	0	0	0	0	0	0	13502460
3.	200	100	100	2000	1	100	100,000	0	0	0	0	0	0	13502460
4.	200	100	100	2200	1	100	100,000	0	0	0	0	0	0	13502460
5.	200	100	100	2900	1	100	100,000	0	0	0	0	0	0	13502460
6.	300	150	150	3150	1	100	150,000	0	0	0	0	0	0	13502460
7.	300	150	150	4500	1	100	150,000	0	0	0	0	0	0	13502460
8.	300	150	150	5155	1	100	150,000	0	0	0	0	0	0	13502460
9.	300	150	150	6075	1	100	150,000	0	0	0	0	0	0	13502460
10.	300	150	150	6300	1	100	150,000	0	0	0	0	0	0	13502460
11.	400	200	200	1500	1	100	200	0	0	0	0	0	0	13502460
12.	400	200	200	2250	1	100	200	0	0	0	0	0	0	13502460
13.	400	200	200	3000	1	100	200	0	0	0	0	0	0	13502460
14.	400	200	200	3750	1	100	200	0	0	0	0	0	0	13502460
15.	400	200	200	4500	1	100	200	0	0	0	0	0	0	13502460
16.	400	8	60	1306	1	100	400,000	0	0	30.	20.	16,000	30,000	135[illegible]60
17.	400	8	60	2443	1	100	400,000	0	0	30.	20.	16,000	30,000	13502460
18.	400	8	60	1306	1	100	400,000	0	0	30.	20.	20,000	120,000	13502460
19.	400	8	60	2443	1	100	400,000	0	0	30.	20.	20,000	120,000	13502460
20.	400	8	60	1616	1	100	400,000	5	50	30.	40.	16,000	30,000	13502460
21.	400	8	60	2036	1	100	400,000	5	50	30.	40.	16,000	30,000	13502460
22.	400	8	60	1616	1	100	400,000	5	50	[illegible]	40.	20,000	120,000	13502460
23.	400	8	60	2036	1	100	400,000	5	50	30.	40.	20,000	120,000	13502460
24.	400	4	12	1382	1	100	400,000	0	0	30.	80.	16,000	30,000	13502460
25.	400	4	12	2676	1	100	400,000	0	0	30.	80.	16,000	30,000	13502460
26.	400	4	12	1382	1	100	400,000	0	0	30.	80.	20,000	120,000	13502460
27.	400	4	12	2676	1	100	400,000	0	0	30.	80.	20,000	120,000	13502460
28.	1000	50	50	2900	1	100	1,000,000	0	0	0	0	0	0	13502460
29.	1000	50	50	3400	1	100	1,000,000	0	0	0	0	0	0	13502460
30.	1000	50	50	4400	1	100	1,000,000	0	0	0	0	0	0	13502460
31.	1000	50	50	4800	1	100	1,000,000	0	0	0	0	0	0	13502460
32.	1500	75	75	4342	1	100	1,500,000	0	0	0	0	0	0	13502460
33.	1500	75	75	4385	1	100	1,500,000	0	0	0	0	0	0	13502460
34.	1500	75	75	5107	1	100	1,500,000	0	0	0	0	0	0	13502460
35.	1500	75	75	[illegible]	1	100	1,500,000	0	0	0	0	0	0	13502460

TABLE IV

Optimal Objective Function Value

Problem No.	Objective Function Value
1	2054059
2	1818866
3	1646007
4	1332598
5	1374153
6	2135438
7	1818475
8	1803322
9	1650449
10	1988555
11	4991
12	3843
13	3048
14	2392
15	2460
16	66644957
17	33296481
18	62451490
19	33296481
20	79562354
21	25214811
22	78868140
23	24765976
24	80022555
25	69302042
26	67799030
27	51296683
28	131264893
29	114387763
30	86559373
31	80333340
32	207885203
33	182406145
34	152264683
35	150900302

REFERENCES

1. Klingman, D., A. Napier, and J. Stutz, "NETGEN: A Program for Generating Large-Scale Capacitated Assignment, Transportation, and Minimum Cost Network Flow Problems," *Management Science*, 8 (1974), 814-821.

2. Learmouth, G. P., and P. A. W. Lewis, "Statistical Tests of Some Widely Used and Recently Proposed Uniform Random Number Generators," NPS55LW73111A, Naval Postgraduate School, Monterey, California, November 1973.

3. Lewis, P. A. W., A. S. Goodman, and J. M. Miller, "Pseudo-Random Number Generator for the System/360," *IBM Systems Journal*, 8 (1969), 136-145.

4. "Out-of-Kilter Network Routine," SHARE Distribution 3536, SHARE Distribution Agency, Hawthorne, New York, 1967.

APPENDIX

Installation and Use of NETGEN

Installation

NETGEN is a stand-alone FORTRAN program. It utilizes three files which must be defined by the user as necessary on the computer system being used.

File Name	Use
TAPE 5	Input file containing the definitions of the problems to be generated.
TAPE 7	Output file containing a summary report on the generated problems formatted for printing.
TAPE 3	Output file containing the problems generated.

Each of these files is a formatted file with record lengths of 80 characters for TAPE 5 and TAPE 3 and 132 characters for TAPE 7.

Data Preparation

The data (input) deck must contain 2 cards (punched according to the format below) for each problem desired. The program will generate a separate network problem for each pair of cards in the data deck. The pair of cards defining the last problem must be followed by a blank trailer card.

The following are the input requirements for each problem:

COLUMNS	CONTENTS	VARIABLE (TYPE)
Card 1.		
1-8	8 digit positive integer to initialize the random number generator. (Must have at least one non-zero digit in columns 1-8)	ISEED
Card 2.		
1-5	Total number of nodes....................	NODES
6-10	Total number of source nodes (including transshipment sources)....................	NSORC
11-15	Total number of sink nodes (including transshipment sinks)......................	NSINK
16-20	Number of arcs............................	DENS
21-25	Minimum cost for arcs.....................	MINCST
26-30	Maximum cost for arcs.....................	MAXCST
31-40	Total supply..............................	ITSUP
41-45	Number of transshipment source nodes......	NTSORC
46-50	Number of transshipment sink nodes........	NTSINK
51-55	Percentage of skeleton arcs to be given the maximum cost..........................	IPHIC
56-60	Percentage of arcs to be capacitated......	IPCAP
61-70	Minimum upper bound for capacitated arcs..	MINCAP
71-80	Maximum upper bound for capacitated arcs..	MAXCAP

All input values on card 2 are integers and must be right--justified in their field. The variables IPHIC and IPCAP should be in the range 0 to 100, inclusive.

To generate transportation and assignment problems the number of sources plus the number of sinks must equal the total number of nodes and the number of transshipment sources and sinks must be equal to zero (i.e., NSORC + NSINK = NODES and NTSORC = NTSINK = 0). In addition, to create assignment problems the number of sources must equal the number of sinks and the total supply must be equal to the number of sources (i.e., NSORC = NSINK = ITSUP).

The maximum number of arcs which the program will create is equal to the number of pure sources (NPSORC = NSORC - NTSORC) times the remaining nodes (NONSORC = NODES - NPSORC) plus the total number of transshipment nodes (NODES - NSORC + NTSORC - NSINK + NTSINK) times NONSORC - 1. If the user asks for this number of arcs or greater the network produced will contain this number of arcs. (Note: A network containing this number of arcs is totally dense.)

Output Format

The program writes two files, an output file (printer) and a problem file (tape, disk or cards). The problem file (TAPE 3) contains all of the problems requested in a format compatible with SHARE [4] input format. Each problem consists of a set of card images written as follows (beginning in column 1):

```
BEGIN   (additional title information)
Title card for this problem
ARCS    (additional title information)
        arc data cards
END
SOLVE
```

Each of the arc data cards is written as follows:

cols.	1-6	blank
	7-12	number of "from" node
	13-18	number of "to" node
	19-20	blank
	21-30	cost
	31-40	upper capacity
	41-50	lower capacity

Table II contains the arc data cards (as written on the problem file) for the problem specification given in Table I. (Note that all the arcs emanating from a node appear together.) The three header cards (BEGIN, title, ARCS) for this problem are given below:

```
BEGIN    RANDOM NUMBER GENERATOR SEED = 12345678, PERCENT HI CST = 35
NODES = 12, SOURCE = 3, SINK = 4, ARCS = 32, COST = 10 - 100, SUPPLY = 750
ARCS     TSORCE = 0, TSINK = 2, CAP = 100 - 400, PERCENT CAP = 70
```

A file containing n problems will appear as follows:

```
BEGIN
title card
ARCS
                      arc data cards          Problem 1
END
SOLVE
        .
        .
        .
BEGIN
title card
ARCS
                      arc data cards          Problem n
END
SOLVE
QUIT
                                              End of File
```

The output file (TAPE 7) consists of a summary of the user input specifications and the actual number of arcs generated for each problem. Table 1 is similar to the summary produced by the code.

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13. ABSTRACT

The purpose of this note is to describe a modified version of the computer program NETGEN, which can be used to generate network flow problems for testing and validation purposes. The paper also presents solutions for a set of 35 benchmark problems.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Transportation Problems						
Network Problems						
Transshipment Networks						
Assignment Problems						
Network Times						
Transportation Times						
Assignment Times						